

Section of Radiology

President George Simon MD

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with the Faculty of Radiologists and
the British Institute of Radiology*

Particle Beam Therapy [Summary]

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Physical Aspects of Particle Beam Therapy

The advantage of particle beams in radiotherapy arises from their possession of one or more of the following properties: (1) Well-defined range in tissue. (2) Little scattering in passage through the body. (3) Gradual increase of the specific ionization along range with high peak near the end of the range (Bragg-peak). (4) High LET (linear energy transfer), with the consequent elimination of the disadvantageous difference in radiation sensitivity between oxygenated and hypoxic tissue.

The particles which could be used in radiotherapy are: electrons, neutrons, protons,

π -mesons. The use of π -mesons is based on their property of producing α -particles and heavier ions when they are stopped in matter.

Electrons have only property (1), and even this is not well defined, but nevertheless there are advantages in using electrons in some cases in radiotherapy. The claim for the advantage of neutrons rests entirely on (4). High energy protons, deuterons and α -particles have properties (1), (2) and (3), and are particularly useful for radiosurgery. Heavy ion and π -meson beams possess all the advantageous properties enumerated above, and therefore appear to offer the best hope for a major advance in radiotherapy; however, the accelerators necessary to produce such beams in usable intensity are extremely expensive.

Electron Beam Therapy

suggested as a control of ionimetric methods for radiobiological and clinical application.

Other working groups are tackling the problem of γ -rays which always accompany the electron beam and seeking to clarify the well-known difference between the relative biological effectiveness (RBE) of the range 5–15 MeV and that of the higher energies. The physical advantages of using electron therapy in tumours up to a certain depth below the surface diminishes in energies over 15 MeV but rotation therapy and especially the electronic lens allows these to operate even in higher energies. There are some facts that suggest biological reasons why electrons may, in some cases, be more effective than photons. One can irradiate tumours in regions of highly sensitive normal tissue such as the female and male superficial genital areas with a good chance of cure. Also recurrences after previous irradiation seem

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Personal Experience and Review of the Montreux Symposium¹

In Montreux, the majority of scientists and physicists directly engaged in this work sought to collate the available knowledge about electron therapy and to try to answer questions of particular importance. Working groups were formed to solve the problems of dosimetry and to work out recommendations for the practical application of electrons. Ferrosulphate dosimetry was deuterons, α -particles, heavy ions and negative

¹Symposium on High Energy Electrons (Physical, Biological and Therapeutic Aspects), Montreux, September 7–11, 1964 (in press)

to have a better chance of eradication with electrons than with photons.

It is possible to influence several tumours which so far have been considered radioresistant. This is the case in mixed tumours of the parotid, synoviomias, fibro-, spindle-, lipo-, myso- and polymorphonuclear cell sarcoma. Adenocarcinoma of the gastro-intestinal tract shows a good response but pre-operative irradiation is recommended as the routine technique because of the high sensitivity of the mucous membrane. In 157 cases in Berne of pre-operative treatment of tumours variously located, we found a good regression of the tumour and a low rate of operative and post-operative complications.

The clinical experiences recounted at Montreux can be summed up as follows: Good results were obtained in extensive skin and lip cancers, melanomas, oral cancers, struma maligna, breast cancer, cancer of the cervix in pregnancy, and lung cancer, but in the last group only by one author. In hypopharynx and bladder cancer as well as in brain tumours the amelioration is doubtful but the technique can still be improved upon. Electrons have some physical and probably some biological advantages which justify their clinical application and which call for further investigations.

Dr Robert Morrison
(*Hammersmith Hospital, London*)

Electron Therapy at 8 MeV

Physical Properties of the Electron Beam

The beam is emitted from the end of the accelerating tube of the linear accelerator as a pencil of radiation 1 cm in diameter. To give a uniform treatment over a reasonable area the beam passes through scattering material made of gold foil, 0.11 mm thick. Whole body irradiation is given by an open field but for the treatment of localized tumours the beam is defined by a suitable applicator fixed to the end of a metal collimating cylinder 1 metre long. When the full depth of penetration is not required the energy of the electrons can be reduced by passing the beam through a block of carbon 1.5 cm thick.

The central axis depth dose from the beam scattered by the gold foil rises from 90% on the skin surface to 100% at 1.5 cm deep and thereafter there is a steep fall almost to zero at about 4 cm which is the maximum range of the electrons. The 80% dose level falls at 2.5 cm deep which is the maximum depth of effective treatment.

Clinical Application

In general, this radiation can be used as an alternative to a radium applicator in the treatment of localized skin tumours, and it avoids the radiation hazard associated with the handling of radium. It is particularly suitable for lesions on the surface of the body where irradiation of the deeper tissues has to be reduced to a minimum, for example in the treatment of tumours of the scalp or of nodules on the chest wall in breast cancer. It is also a satisfactory method of irradiation of the chest wall after mastectomy, although the penetration of the electrons is not great enough to treat the internal mammary nodes.

Because of the low dose received by the deeper tissues, and particularly the bone marrow, this energy of electron radiation is particularly useful for the treatment of extensive skin diseases, such as mycosis fungoides and diffuse infiltration of the skin by the reticulososes. In these conditions doses of 1,500–2,000 rads may be given in a period of three to four weeks without systemic upset or any significant depression of the white cell count.

Apparatus

Electron therapy in the 2–10 MeV energy range can be generated by a linear accelerator which is modified to allow the electron beam to be extracted. It would be an advantage for the electron radiation to emerge from the machine from the same port as the X-rays. To achieve this either the electron beam has to be deflected away from the target, or the target and the beam flattening filter have to be moved aside. In the recently designed linear accelerators both these methods have been adopted and appear to work satisfactorily.

Dr H W C Ward and Dr A Jones (*St Bartholomew's Hospital, London*) presented a paper entitled **The Clinical Application of 15 MeV Electrons**

The Prospects for Neutron Therapy

Professor J F Fowler
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Oxygen Enhancement Ratios and Depth Doses as Opposing Factors in Fast Neutron Therapy

X-rays and electrons are lightly ionizing radiations and are less effective in killing anoxic cells than